PHOSPHOR HANDBOOK

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Edited under the Auspices of

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CRC Press
Boca Raton Boston London New York Washington, D.C.

Acquiring Editor: Robert Stern
Project Editor: Albert W. Starkweather, Jr.
Cover design: Dawn Boyd

Library of Congress Cataloging-in-Publication Data

Phosphor handbook / edited under the auspices of the Phosphor Research Society ; editorial committee co-chairs Shigeo Shionoya, William M. Yen ; members Takashi Hase ... [et al.]
p. cm.
Includes bibliographical references and index.
ISBN 0-8493-7560-6 (alk. paper)
1. Phosphors–Handbooks, manuals, etc. 2. Phosphors–Industrial applications–Handbooks, manuals, etc. I. Phosphor Research Society.
QC476.7.P48 1998
620.1′1295—dc21 98-15663
CIP

Originally published in Japanese by Ohmsha, Ltd. under the title *Keikotai Handobukku.*

No claim to original U.S. Government works
International Standard Book Number 0-8493-7560-6
Library of Congress Card Number 98-15663
Printed in the United States of America 1 2 3 4 5 6 7 8 9 0
Printed on acid-free paper

Table 1 Various Characteristics of X-ray Phosphors

Phosphor	Emission spectrum: Emission color	Emission spectrum: Peak wavelength (nm)	Emission efficiency (%)	X-ray absorption: Effective atomic number	X-ray absorption: K-edge (keV)	Specific gravity	Crystal structure
$BaFCl:Eu^{2+}$	Violet	380	13[a,b]	49.3	37.38	4.7	Tetragonal
$BaSO_4:Eu^{2+}$	Violet	390	6[a,b]	45.5	37.38	4.5	Rhombic
$CaWO_4$	Blue	420	5[c]	61.8	69.48	6.1	Tetragonal
$Gd_2O_2S:Tb^{3+}$	Green	545	13[d]	59.5	50.22	7.3	Hexagonal
$LaOBr:Tb^{3+}$	Whitish-blue	420	20[e]	49.3	38.92	6.3	Tetragonal
$LaOBr:Tm^{3+}$	Blue	360, 460	14[e]	49.3	38.92	6.3	Tetragonal
$La_2O_2S:Tb^{3+}$	Green	545	12.5[d]	52.6	38.92	6.5	Hexagonal
$Y_2O_2S:Tb^{3+}$	Whitish-blue	420	18[a,b]	34.9	17.04	4.9	Hexagonal
$YTaO_4$	Ultraviolet	337	—	59.8	67.42	7.5	Monoclinic
$YTaO_4:Nb$	Blue	410	11[f]	59.8	67.42	7.5	Monoclinic
ZnS:Ag	Blue	450	17[d]	26.7	9.66	3.9	Hexagonal
(Zn,Cd)S:Ag	Green	530	19[d]	38.4	9.66/26.7	4.8	Hexagonal

[a] Measured value by cathode-ray excitation.
[b] From Stevels, A.L.N. and Pingault, F., *Philips Res. Rep.*, 30, 277, 1975.
[c] From Coltman, J.W., Ebbighausen, E.G., and Altar, W., *J. Appl. Phys.*, 18, 583, 1947.
[d] From de Pooter, J.A. and Bril, A., *J. Electrochem. Soc.*, 122, 1086, 1975.
[e] From Rabatin, J.A., *Abstr. Electrochem. Soc., Spring Meeting*, 825, 1978.
[f] From Brixner, L.H. and Chen, H.-Y., *J. Electrochem. Soc.*, 130, 2435, 1983.

3. Medical diagnosis, luggage inspection at airports, and nondestructive industrial testing is accomplished by capturing the image on the fluorescent screen with an image pickup tube and observing the image on a TV monitor.

7.1.2.2 *Phosphors used in X-ray fluorescent screens*

In the early days of X-rays, $BaPt(CN)_4{\cdot}4H_2O$ phosphor was used. However, because of its high cost and chemical instability, this phosphor was later replaced by $ZnSiO_4:Mn^{2+}$ and $CdWO_4$.

Around 1930, (Zn, Cd)S:Ag was developed. This phosphor greatly increased the brightness of fluorescent screens, and is currently still in use. About 10 years ago, $Gd_2O_2S:Tb^{3+}$ came into use for applications in combination with a mirror camera or image pickup tube, as described above.

7.1.2.3 *Structure and characteristics of X-ray fluorescent screens*

As can be seen from the structure illustrated in Figure 8, an X-ray fluorescent screen is composed of a reflective layer deposited on one side of a high-quality paper or plastic base, with a 200- to 300-μm-thick phosphor layer coated on top.

In fluorescent screens for radiology use, (Zn, Cd)S:Ag phosphors are used; an emission peak wavelength at 525 nm, providing a spectral luminous efficacy that allows the X-ray image on the fluorescent screen to be seen by the human eye. Because brightness is a very important requirement, a large-grain (average 20 to 40 μm) phosphor is used.

In a fluorescent screen for direct viewing, the minimum identifiable image size, *d*, is related to the brightness of the screen, *B*, and the contrast of the screen, *C*, by the following equation.

$$d = \frac{k}{C\sqrt{B}} \tag{1}$$

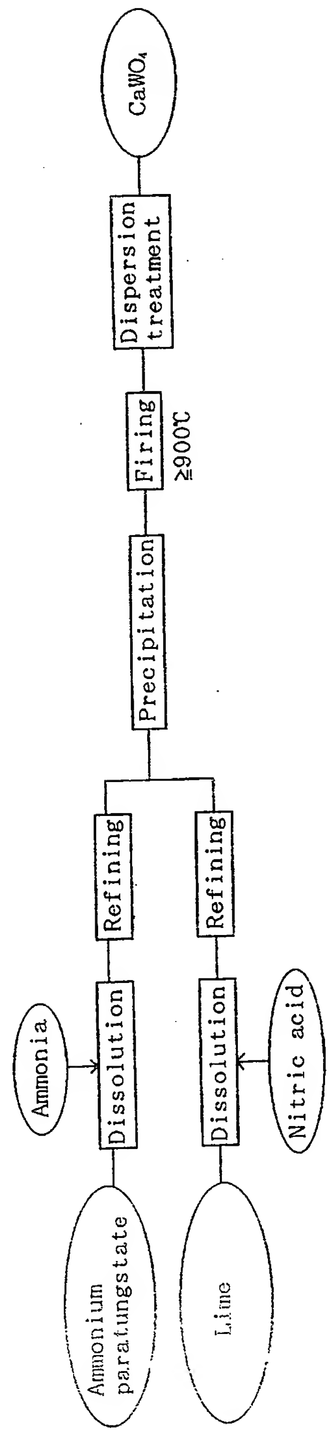

Figure 6 Production process of the $CaWO_4$ phosphor.

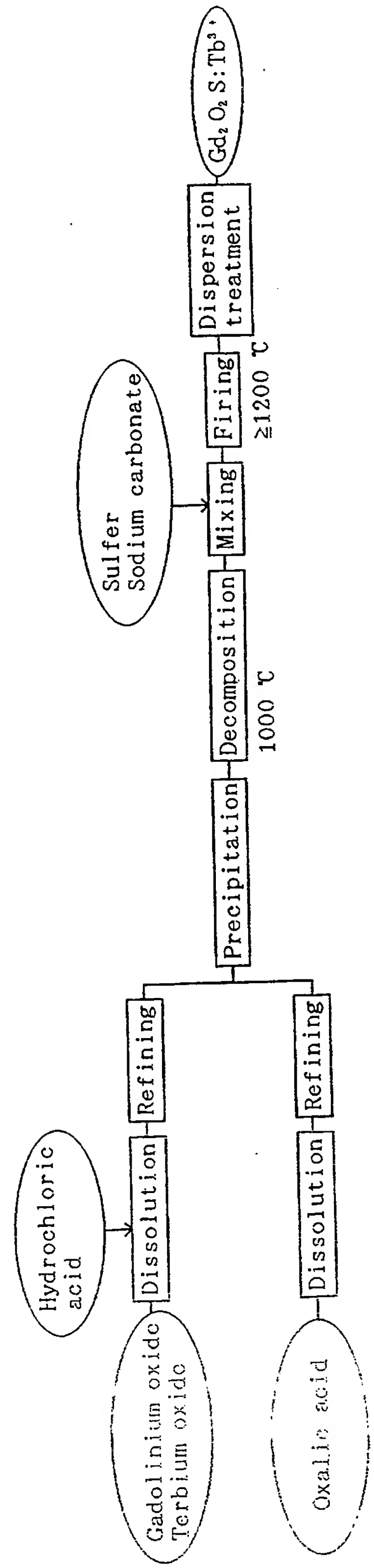

Figure 7 Production process of the $Gd_2O_2S:Tb^{3+}$ phosphor.

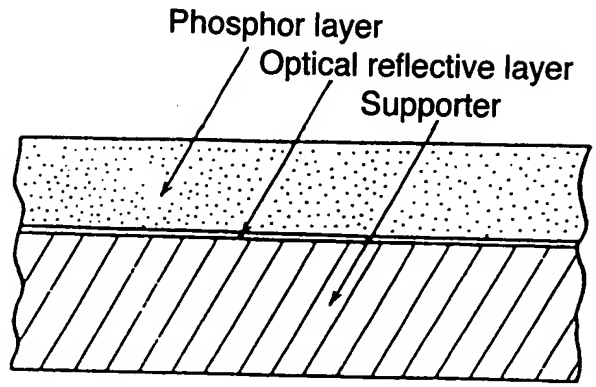

Figure 8 Structure of an X-ray fluorescent screen.

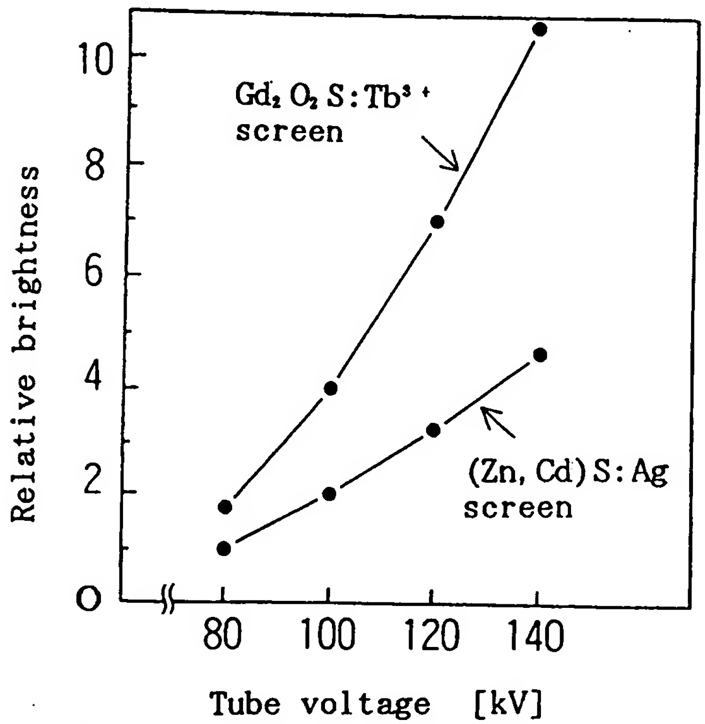

Figure 9 Comparison of the speed of $Gd_2O_2S:Tb^{3+}$ and (Zn, Cd)S:Ag fluorescent screens.

Fluorescent screens for fluoroscopy use the (Zn, Cd)S:Ag phosphor, which has an emission peak at 540 nm, matching the spectral sensitivity of a radiographic film. Recently, screens using the $Gd_2O_2S:Tb^{3+}$ phosphor have been replacing (Zn, Cd)S:Ag screens. The $Gd_2O_2S:Tb^{3+}$ fluorescent screens are superior to the (Zn, Cd)S:Ag phosphor screens in such basic characteristics as speed (the product of the X-ray absorption coefficient and the emission efficiency) and sharpness. The speed characteristics of fluorescent screens for fluoroscopy under the conditions of chest radiography are compared in Figure 9; sharpness characteristics are compared for the same conditions in Figure 10.

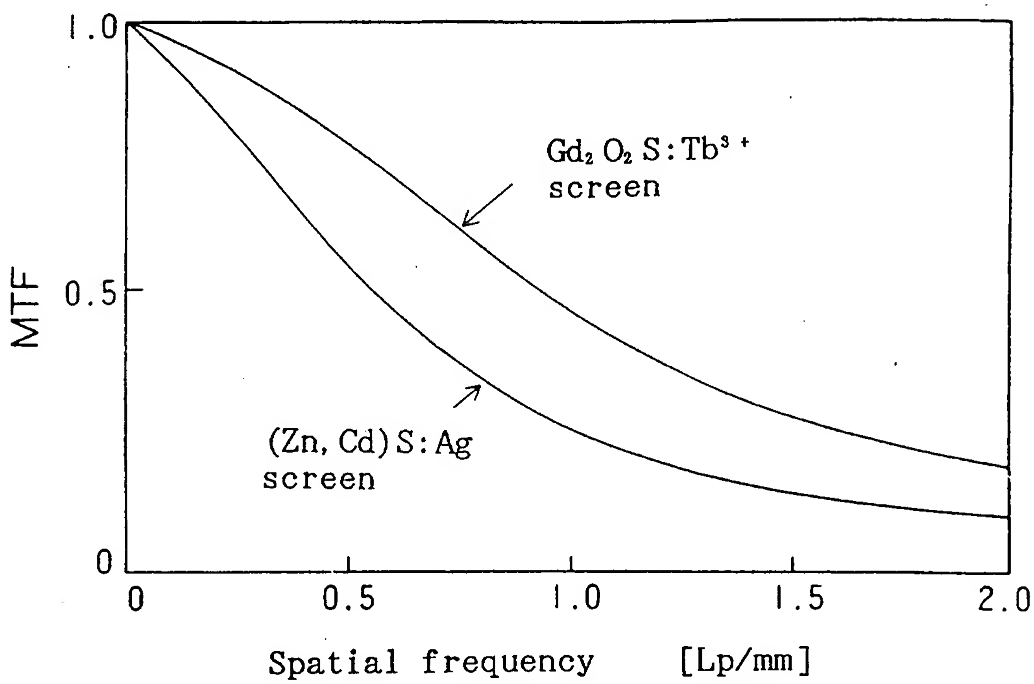

Figure 10 Comparison of the sharpness of $Gd_2O_2S:Tb^{3+}$ and (Zn, Cd)S:Ag fluorescent screens.

7.2 Phosphors for thermoluminescent dosimetry

7.2.1 The principle of thermoluminescent dosimetry

When substances that have been irradiated by X-rays or gamma rays are heated, a phenomenon called thermoluminescence can occur. An example of the application of this phenomenon in the measurement of radiation is the thermoluminescent dosimeter system. The function of phosphors in that system are explained below.

Irradiated phosphors absorb some of the radiant energy, producing free electrons and holes within the phosphor crystals. The electrons are captured by lattice defects (F-center, etc.), creating a metastable state. If a phosphor in that state is heated, the captured electron is released and recombines with a trapped hole, returning to the ground state. By that recombination, luminescence is produced. Thermoluminescent phosphors are so designed that they remain in the metastable state and do not easily radiate the trapped energy unless subjected to an intentional external disturbance such as heating.

The detailed mechanism of thermoluminescence varies with the substance. This is a complex issue, but consider here a simple system that has only one type of metastable state. Let n be the number of luminescence centers that are in the metastable state, $s\exp(-\varepsilon/kT)$ the probability of release from the metastable state, and $dT/dt = \beta$ the rate of temperature increase of the phosphor. Then,

$$-\frac{dn}{dt} = ns\exp\frac{-\varepsilon}{kT} \tag{2}$$

By replacing dt by dT and integrating the above equation, one obtains:

Internationales Büro
INTERNATIONALE ANMELDUNG VERÖFFENTLICHT NACH DEM VERTRAG ÜBER DIE INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES PATENTWESENS (PCT)

(51) Internationale Patentklassifikation 6 : H01L 33/00, H01S 3/19 — A1

(11) Internationale Veröffentlichungsnummer: WO 98/12757

(43) Internationales Veröffentlichungsdatum: 26. März 1998 (26.03.98)

(21) Internationales Aktenzeichen: PCT/DE97/02139

(22) Internationales Anmeldedatum: 22. September 1997 (22.09.97)

(30) Prioritätsdaten:
196 38 667.5 20. September 1996 (20.09.96) DE

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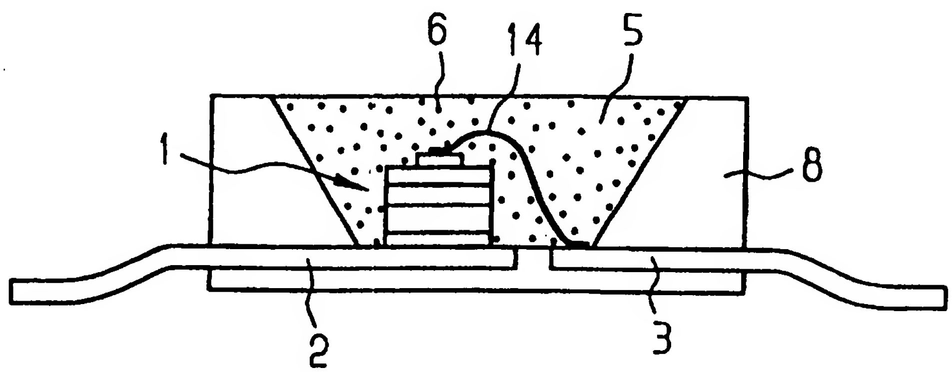
(81) Bestimmungsstaaten: BR, CN, JP, KR, US, europäisches Patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Veröffentlicht
Mit internationalem Recherchenbericht.
Vor Ablauf der für Änderungen der Ansprüche zugelassenen Frist. Veröffentlichung wird wiederholt falls Änderungen eintreffen.

(54) Title: SEALING MATERIAL WITH WAVELENGTH CONVERTING EFFECT, APPLICATION AND PRODUCTION PROCESS

(54) Bezeichnung: WELLENLÄNGENKONVERTIERENDE VERGUSSMASSE, DEREN VERWENDUNG UND VERFAHREN ZU DEREN HERSTELLUNG

(57) Abstract



The present invention pertains to a sealing material (5) with wavelength converting effect, obtained by mixing epoxy cast resin with a luminescent substance and intended for use in an electroluminescent building component comprising a body (1) emitting an ultraviolet light, blue or green, and spraying in the epoxy cast resin a powder of inorganic luminescent pigments (6) from the phosphor group of general formula $A_3B_5X_{12}$:M, with a grain size ≤10 μm and a grain diameter d_{50} ≤5 μm.

(57) Zusammenfassung

Wellenlängenkonvertierende Vergußmasse (5) auf der Basis eines transparenten Epoxidgießharzes, das mit einem Leuchtstoff versetzt ist, für ein elektrolumineszierendes Bauelement mit einem ultraviolettes, blaues oder grünes Licht aussendenden Körper (1). Im transparenten Epoxidgießharz ist ein anorganisches Leuchtstoffpigmentpulver mit Leuchtstoffpigmenten (6) aus der Gruppe der Phosphore mit der allgemeinen Formel $A_3B_5X_{12}$:M dispergiert und die Leuchtstoffpigmente weisen Korngrößen ≤10 μm und einen mittleren Korndurchmesser d_{50} ≤5 μm auf.